15135

10.P.

Ohio
Department of
Natural
Resources

COASTAL HAZARDS:

RECESSION, EROSION AND FLOODING

Ohio Natural Resources.

CZM

Ohio Coastal Zone Management Program

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER
COASTAL ZONE MANAGEMENT SECTION

COASTAL HAZARDS: RECESSION, EROSION AND FLOODING

prepared for the
Coastal Zone Management Program
by

Charles H. Carter and Bruce E. McPherson

October 1977

This publication was financed in part by a federal grant from the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, under the provision of Section 305 of the Coastal Zone Management Act of 1972 (P.L. 92-583).

JAMES A. RHODES, *Governor* • ROBERT W. TEATER, *Director* • WAYNE S. NICHOLS, *Chief*

CONTENTS

I
SHORELINE RECESSION AND EROSION

Introduction

The shoreline erosion section of this report presents a summarized county by county description of the Ohio shore of Lake Erie including information on the rates at which the shore of Lake Erie is receding. It is based on the data compiled by the Ohio Department of Natural Resources, Division of Geological Survey for detailed shore erosion investigation reports to be published over the next two years. Many natural, cultural, and manmade features along the shore affect the rate of erosion and the natural littoral deposition process. This information facilitates decisions and planning related to shore erosion. Such decisions are necessary because of increased development along the shore and the greater probability of increased damage. Erosion not only causes loss of property, but also results in sedimentation of silt and clay which contributes to the eutrophication of Lake Erie.

Maps and photographs from three years--1876, 1937, and 1973--were selected for use in calculating the rate at which erosion has occurred along the south shore of Lake Erie. The 1876 maps are the first detailed maps of the entire Ohio shore of Lake Erie. The 1937 photographs are one of the first series of aerial photographs taken of the entire Ohio shore of Lake Erie, and the 1973 photographs are one of the latest series.

The recession rate information provided in this report is described according to various rate classes such as slow, moderate, rapid, etc. The quantitative equivalents of these rate classes are as indicated below.

Recession Rate Class	Rate (Ft/yr)
Very slow	<1
Slow	1-3
Moderate	3-5
Rapid	5-7
Very Rapid	7-9

Shore Processes

Shore erosion, the loss of shoreland, can be related to many processes, but along the Lake Erie shore, there are two principal shore erosion processes: wave erosion and mass wasting. Of the two processes, wave erosion is by far the more significant. These processes erode the Lake shore at different rates because of two primary factors: the physical setting and the weather. Variation in recession rates among different reaches along the shore and through time generally can be related to these two factors.

Surface waves, which are generated by wind blowing across the lake, are the principal cause of recession along the Lake Erie shore because waves contain a great deal of energy that is released when the waves deform and break. Although some of the energy is returned to the lake through reflection and other types of wave-related movement, much of the energy is expended in wave erosion of the nearshore, beach and shoreline, and shore zones.

The effect of nearshore slope on wave energy can be looked at in this general way: (1) wave energy is related directly to wave height; (2) waves deform and break (lose their height) when the water depth is about one to two times the wave height; (3) therefore the gentler the nearshore slope, the farther offshore waves break and the greater the decrease in wave energy reaching the shoreline. Once the waves reach the shoreline a wide beach will absorb most of the wave energy, but along the stretches with narrow beaches a much greater proportion of the wave energy will reach the shore.

Lastly, because of the nearly continuous removal of slumped or inplace material, which acts as a resisting moment at the base of the slope or bluff, the shore bluff or slope does not at any time reach a long-term equilibrium. Therefore, recession is continuous.

Mass wasting is basically the downslope movement of material by gravitational stress. Along the Ohio shore of Lake Erie the principal mass-wasting processes are block falls, rotational slumps, debris flows, and piping.

Block falls, which are the relatively free-falling movement of coherent material, are caused by wave erosion undercutting the base of a bluff. Rotational slumps, which are a shearing and rotary movement of material along a curved slip surface, appear to be controlled by laminated clay zones within or above the till. When a clay zone becomes lubricated, either from water updip or from surface water percolating down along joint planes, the zone acts as a slip plane upon which the shore material slumps. Debris flows, which are the downward movement of a mass of incoherent material, are most pronounced where there are interbedded sands. Water percolating down from the overlying sands and/or running along the sand-clay interface saturates the clay. This increase in moisture reduces the internal shear resistance of the clay and this, as well as the weight of the overlying sand, causes the clay to deform and flow. Piping, which is erosion by percolating water, is common along sand-clay contacts. Water flowing through an overlying sand layer is concentrated at the clay contact; the consequent decrease in the shear strength of the sand at the contact causes the sand to collapse.

LUCAS COUNTY

Setting

The sparsely to densely built-up Lucas County shore fronts 23 miles (37 km) of the westernmost portion of Lake Erie and lies between Michigan to the northwest and Ottawa County to the east. Shore deposits consisting largely of glaciolacustrine clay make up the low relief banks of about 5 feet (1.5 m) that border Maumee Bay, whereas sand and marshes make up the low relief slopes of about 5 feet (1.5 m) that border Cedar Point to the Lucas-Ottawa County line (western basin shore). Sand beaches are small or nonexistent along the Maumee Bay shore, whereas discontinuous beaches front 44% of the open lake shore. In addition to the beaches, shore protection structures or manmade fill fronts much of the Maumee Bay shore and some of the open lake shore, particularly in front of Reno Beach. Over 244 shore-protection structures were inventoried in 1973. The nearshore slope is gentle along the entire county; the average water depth 500 feet (152 m) offshore at a lake-level elevation of 570.0 feet is about 4 feet (1.2 m) in Maumee Bay and about 7 feet (2.1 m) in the open lake. The nearshore bottom, within 2,000 feet (610 m) of shore, consists of mud and/or glaciolacustrine clay along Maumee Bay and sand and/or glaciolacustrine clay along the western basin shore. The sand for the most part is no more than 5 feet (1.5 m) thick.

Shore Processes

Storm waves appear to be the principal cause of erosion along the Lucas County shore. Wave erosion removes in-place and slumped material near lake level, thus maintaining an unstable bank or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits, resulting in greater recession rates.

Mass wasting follows wave erosion in the glaciolacustrine clay deposits along Maumee Bay. Block falls are fairly common in this cohesive shore deposit; failure of the clay blocks takes place days, weeks, or even months after wave erosion.

Inundation (flooding) is a major problem along most of the Lucas County shore because of low relief and location at the western end of the lake. Northeast storms generated by low pressure systems passing to the south are largely responsible for the wind setup which can reach several feet above the lake's still-water level. Northeast storms in combination with record high lake levels, were responsible for the damaging floods in late 1972 and in 1973.

Shoreline Changes

The principal change in the Lucas County shore from 1877 to 1973 has been the increase in unevenness of the shore. The 1877 shore, in general, had a fairly even, uniform shape, whereas the 1973 shore has a much more uneven, nonuniform shape, particularly in the more intensely developed areas. The change in shape can be related directly to manmade structures--these structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1877 waves impinged upon a largely natural Lucas County shore. However, since the construction of manmade structures the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the longshore drift of sand, have had a great influence on shoreline changes and recession rates along the western basin shore; however, along the Maumee Bay shore these structures have had little effect because of the lack of sand. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope; loss of sand to the adjacent downdrift shore results in a narrower beach and a steeper nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate; on the downdrift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate. Particularly noteworthy among the stickout structures for their effect on the shore are the ones at Lakemont Landing and west of Crane Creek State Park.

Parallel structures--seawalls and breakwaters--have reduced erosion along the Maumee Bay and western basin shore by protecting the base of the shore. The most notable examples of this type of protection are along the stretches fronting Point Place and Oregon on Maumee Bay and between Wards Canal and Lakemont Landing along the western basin. Unlike the stickout structures, the parallel structures, which consist largely of seawalls, do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. In general, in the late period, along stretches where there is a concentration of structures, the recession rate is slower than that of the early period, when there were fewer structures.

Beaches

Nearly continuous, but narrow, beaches front the western basin shore; beaches are essentially nonexistent in Maumee Bay. In general, the stretches with the largest beaches, such as the stretch fronting Crane Creek State Park and the stretch east of Lakemont Landing, have low recession rates. On the other hand, where there are narrow beaches less than 50 feet wide (15.2 m) in combination with an unprotected shore or where the beaches were eroded away--as along stretches to the west (downdrift) of Crane Creek State Park and the stretch downdrift of Lakemont Landing--the recession rates are high.

Recession Rates 1877-1940

The modal recession rate was between 5-7 ft/yr (1.5-2.1 m) and the range in recession rates was very slow, less than 1 ft/yr (.3 m), to 13-15 ft/yr (3.9-4.5 m) along the western basin shore; the modal recession rate was very rapid, 7-9 ft/yr (2.1-2.7 m), and the range in recession rates was very slow to 9-11 ft/yr (2.7-3.3 m) along the Maumee Bay shore. In general, the principal factor contributing to the high rates along both the western basin shore and the Maumee Bay shore is the type of shore deposit. The sand making up the western basin shore has no cohesive resistance to surface waves, and once the glaciolacustrine clay along the Maumee Bay shore becomes weathered it offers only slight resistance to surface waves. The basic reasons for the lower recession rate in sand is that the beaches can build back up given an adequate sand supply and/or a lower lake level; the cohesive deposits cannot do this.

Recession Rates 1940-1973

The modal recession rate was very slow and the range in recession rates was very slow to 13-15 ft/yr (3.9-4.5 m) along the western basin shore; the modal recession rate was slow and the range in recession rates was very slow to 17-19 ft/yr (5.1-5.7 m) along the Maumee Bay shore. Overall, the principal factor contributing to the low recession rates in this period is the presence of the manmade structures; high recession rates have taken place along unprotected stretches fronting the easily eroded sand and glaciolacustrine clay deposits.

Recession Rates 1877-1940 to 1940-1973

For the Lucas County shore (the reaches between the Ottawa-Lucas County line to Cedar Point and along Maumee Bay) the overriding factor contributing to the decrease in the modal recession rate as well as the overall decrease in the length of the shore, which underwent recession at the highest recession rates, is the presence of manmade structures. The increased number of structures, as well as the greater length of shore protected by these structures, is responsible for the decrease in the modal recession rates as well as for the general decrease in shore length receding at high recession rates.

OTTAWA COUNTY

Setting

The sparsely to densely built-up Ottawa County shore fronts about 73 miles (117 km) of shoreline between Lucas County to the west and Erie and Sandusky Counties to the east and south. The shore consists largely of low relief, about 5 foot (1.5 m) slopes made up of sand and marsh between the Lucas-Ottawa County line to the Port Clinton area; the shore consists largely of rock which reaches 50 feet (15.2 m) in height from the Port Clinton area around Catawba Island to the Marblehead lighthouse (including the Bass Islands); and the shore consists largely of 5 to 10 foot (1.5-3.0 m) high, till and glaciolacustrine clay banks south of the lighthouse and along Sandusky Bay except for Bay Point. Sand beaches front much of the shore from the Lucas-Ottawa County line to the Port Clinton area; for the remainder of the county beaches front small coves or are nonexistent except for two prominent exceptions: the East Harbor State Park area and Bay Point. In addition to the beaches, shore-protection structures front much of the county shore, particularly along the more intensively developed stretches made up of sand, till, or glaciolacustrine clay. Over 995 shore protection structures were inventoried in 1973. The nearshore slope is variable. The average water depth 500 feet (152 m) offshore at a lake level elevation of 570.0 feet is about 3 feet (.9 m) between the Lucas-Ottawa County line and the Port Clinton area; variable, a range of about 2-20 feet (.6-6 m) along Catawba Island, Marblehead, and the Bass Islands; and about 4 feet (1.2 m) along Sandusky Bay. The nearshore bottom, within 2,000 feet (610 m) of shore, consists primarily of sand and glaciolacustrine clay between the Lucas-Ottawa County line and the Port Clinton area; of sand, mud, and/or rock along Catawba Island, Marblehead, and the Bass Islands; and of mud along Sandusky Bay.

Shore Processes

Storm waves appear to be the principal cause of erosion along the Ottawa County shore. Wave erosion removes in-place and slumped material near lake level, thus maintaining an unstable bank or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits; consequently, the greater the recession rates.

Mass wasting follows wave erosion in the till and glaciolacustrine deposits along Sandusky Bay as well as in places north and east of the Port Clinton area. Block falls are common in these cohesive deposits, with failure taking place days, weeks, and even months after wave erosion.

Flooding is a major problem along the Ottawa County shore from the Lucas-Ottawa County line to Port Clinton and along Sandusky Bay, because of low relief and location at the western end of the lake. Northeast storms generated by low pressure systems passing to the south are largely responsible for the wind setup which can reach several feet above the lake's still-water level. Northeast storms in combination with record high lake levels were responsible for the damaging floods in late 1972 and 1973.

Shoreline Changes

The principal change in the Ottawa County shore from 1877 or 1939 to 1973 has been the increase in unevenness of the shore. The early shore, particularly from the Lucas-Ottawa County line to Rock Ledge and along Sandusky Bay, was essentially continuous and had a fairly even, uniform shape, whereas the 1973 shore is discontinuous in places and has a much more uneven, nonuniform shape. These changes can be related to manmade structures. These structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1877 waves impinged upon a largely natural Ottawa County shore. However, since the construction of manmade structures the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the transport of sand, have had a great influence on shoreline changes and recession rates along the western basin shore. However, along the Sandusky Bay shore, these structures have had little effect because of the lack of sand. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope; loss of sand to the adjacent downdrift shore results in a narrower beach and a steeper nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate. On the down-drift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate. These structures have had the greatest effect along the shore from the Lucas-Ottawa County line to Rock Ledge. Stickout structures particularly noteworthy for their effect on the shore are the ones at Turtle Creek (which interrupts the net east-to-west drift) and LaCarpe Creek (which interrupts the net west-to-east drift).

Parallel structures--seawalls and breakwaters--have reduced erosion along several Ottawa County stretches by protecting the base of the shore. The most notable examples of this type of protection are along the stretches fronting Rock Ledge east of Port Clinton and Hickory Grove along Sandusky Bay. Unlike stickout structures, parallel structures (which consist largely of seawalls) do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. In general, in the late period, along stretches where there is a concentration of structures, the recession rate is slower than that of the early period, when there were fewer structures.

Beaches

Narrow, but nearly continuous beaches lie between the Lucas-Ottawa County line and Rock Ledge; the widest beaches front the East Harbor and Bay Point areas. In general, along the shore fronted by beaches, the stretches with the widest beaches--such as the ones on the updrift side of the jetties at Turtle Creek and LaCarpe Creek, as well as East Harbor and Bay Point--are characterized by low recession rates. On the other hand, where there are narrow, less than 50 feet wide (15 m) beaches in combination with an unprotected shore or where the beaches were eroded away--as along stretches downdrift of the jetties at Turtle Creek and LaCarpe Creek or along the stretch east of Sand Beach--the recession rates are high.

Recession Rates 1877-1939

The modal recession rate was very slow, less than 1 ft/yr (.3 m), and the range in recession rates was very slow to 9-11 ft/yr (2.7-3.3 m) along the six reaches for which 1877 maps were prepared--the reaches along the mainland shore from the Lucas-Ottawa County line to Bay Point. In general, the principal factor contributing to the low rates along the sand shore west of the Rock Ledge-Port Clinton area was an adequate sand supply; the beaches can build back up given an adequate sand supply and/or a lower lake level. Along the shore from Rock Ledge to Bay Point it is the resistance of the rock to erosion which contributes to low recession rates. The stretches of shore which receded at the highest rates are made up of the least resistant deposits (sand, till, or glaciolacustrine clay).

Recession Rates 1939-1973

The modal recession rate was very slow and the range in recession rates was very slow to greater than 19 ft/yr (5.7 m). The highest recession rates are found along the shore made up of sand, till, or glaciolacustrine clay, whereas the lowest recession rates are found along the shore composed of rock or fronted by wide beaches or manmade structures.

Recession Rates 1877-1939 to 1939-1973

For the reaches that can be compared (between the Lucas-Ottawa County line and Bay Point) the overriding factor contributing to the higher recession rates (as well as the overall increase in shore length which underwent recession at the highest rates) appears to be the high lake periods in the early 1950's and 1970's in concert with northeast storms. The much greater wave energy reaching the relatively long unprotected, easily erodable stretches of shore composed of sand, till, or glaciolacustrine clay has caused the shore to recede more rapidly in the 1939-1973 period.

ERIE AND SANDUSKY COUNTIES

Setting

The physiographically diverse shore of Erie and Sandusky Counties lies along Lake Erie in north-central Ohio. The mainland shore extends from the Lorain-Erie County line to the Cedar Point jetty, a distance of about 21 miles (33 km). It consists (from east to west) of bluffs and slopes of till with a relief of 20 to 30 feet (6-9 m); bluffs, slopes and banks of till and glaciolacustrine clay with a relief of 5 to 10 feet (1.5-3 m); and sand dunes with a relief of 10 feet (3 m) along the Cedar Point spit. Manmade shore-protection structures, which number more than 172, front these deposits along the shore. Adjacent to the structures are beaches which form a discontinuous band all along the shore. The beaches have an average width of less than 50 feet (15.2 m) except for the ones updrift (east of) and adjacent to the sizeable jetties at Huron and Cedar Point. The average water depth 500 feet (152 m) offshore at a lake level elevation of 570.0 feet is about 5 feet (1.5 m) along the eastern one-third of the shore and increases to about 7 feet (2.1 m) to the west. From the Lorain-Erie County line to the Cranberry Creek area the bottom deposits to at least 2,000 feet (610 m) offshore consist of sand and/or shale. Farther to the west the sand at the shoreline grades into silt and finer deposits offshore. These noncohesive deposits for the most part cap till or glaciolacustrine clay, which caps rock.

The south shore of Sandusky Bay, which extends from the Cedar Point causeway to Raccoon Creek, a distance of 23 miles (37 km), consists (where not made up of manmade fill) of banks of glaciolacustrine clay with a relief of 5 to 10 feet (1.5-3 m). Manmade shore-protection structures (excluding the nearly totally protected shore fronting the city of Sandusky from the causeway to Mills Creek) front the small communities along the shore. Beaches are narrow to nonexistent. The average water depth 500 feet (152 m) offshore at a lake level of 570.0 feet is about 3 feet (.9 m). The bottom, except for a band of glaciolacustrine clay which borders the shore, is made up of mud; the mud caps glaciolacustrine clay.

Kelleys Island, which has a shoreline distance of about 11 miles (18 km), consists of banks of limestone-dolomite and till which have a relief of from 5 to 20 feet (1.5-6 m). Manmade shore-protection structures are few in number, as are the narrow gravel beaches. The average water depth 500 feet (152 m) offshore at a lake level of 570.0 feet is about 9 feet (2.7 m). The nearshore bottom is made up of rock or poorly sorted sediment consisting of gravel, sand, silt, and clay-size particles.

Shore Processes

Storm waves appear to be the principal cause of erosion along the shore of Erie and Sandusky Counties. Wave erosion removes in-place and slumped material near lake level, thus maintaining an unstable bluff or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits; consequently, the greater the recession rates.

Mass wasting follows wave erosion. Falls, slumps, and flows are most common where there are stratigraphic or structural differences such as bedding planes, zones of laminated clay within the till, or joints. Because of the largely cohesive nature of the shore deposits, failure of a bluff, slope, or bank may take place days, weeks, or even months after wave erosion.

Shoreline Changes

The principal change in the shore of Erie and Sandusky Counties from 1877 to 1973 has been the increase in the unevenness of the shore, specifically along the Sandusky Bay and Lorain-Erie County line to Cedar Point (mainland) reaches. The shape of the 1877 shore, with the Vermilion, Huron, and Sandusky areas as exceptions, had a relatively even, uniform outline, whereas by 1973 the shape of the shore was uneven and nonuniform. The changes in shape can be related directly to manmade structures. These structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1877 waves impinged upon a largely natural Erie and Sandusky Counties shore. Wave erosion and subsequent mass wasting of the unprotected shore provided sand and gravel to form a nearly continuous ribbon of coarse-grained sediment along the shore in the beach and shoreline and nearshore zones, especially along the mainland shore. Wave erosion and mass wasting are continuing today, but, because of the manmade structures that have been built along the shore, the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the longshore drift of sand, have had the greatest influence on shoreline changes and recession rates along the mainland shore. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate; on the downdrift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate. These changes are most readily seen between Vermilion and Huron, where unprotected stretches just downdrift of the larger stickout structures show moderate recession rates, and stretches just updrift of the structures have very slow recession rates.

Parallel structures--seawalls and breakwaters--have reduced erosion along the mainland and Sandusky Bay reaches by protecting the base of the shore. The most notable examples of this type of protection are along the Penn Central Railroad to Raccoon Creek reach, where there are stretches where the recession rate was as high as 19 to 21 ft/yr (.3 m) in the 1937 to 1973 period. Unlike the stickout structures, the parallel structures, which consist largely of seawalls, do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. However, because the principal source of the beach material is the shore, as it is along the mainland--Lorain-Erie County line to Cedar Point jetty stretch--by protecting the shore the source of beach sediment is largely cut off. In general, in the late period, along stretches where there is a concentration of structures the recession rate is slower than that of the early period, when there were fewer structures.

Beaches

In stretches along the mainland shore (Lorain-Erie County line to Cedar Point) where there were wide, greater than 100 feet (30 m) beaches--for example, the beaches on the updrift (east side) of the jetties at Huron River and at Cedar Point--the recession rate within a given period was very slow. On the other hand, where there were narrow, less than 50 feet (15 m) beaches in combination with an unprotected shore--as along stretches downdrift of stickout structures between Vermilion and Old Woman Creek--the recession rates were slow to moderate. The lack or scarcity of beaches along the Sandusky Bay reaches and the Kelleys Island reach precludes a discussion of the effect of beaches for these reasons.

Recession Rates 1877-1937

The modal recession rate was between very slow and slow, less than 1 to 1-3 ft/yr (.3-.9 m) and the range in recession rates was very slow to moderate between 3-5 ft/yr (.9-1.5 m) along the mainland shore, excluding the Sawmill Creek to Cedar Point jetty reach; the modal recession rate was rapid, between 5-7 ft/yr (1.5-2.1 m) and the range in recession rates was very slow to 21-23 ft/yr (6.4-7 m) along the Penn Central Railroad to Raccoon Creek reach; and the modal recession rate was very slow and the range in recession rates was very slow to moderate along the Kelleys Island reach. In general, the principal factors contributing to the relatively low rates along the mainland shore are the manmade structures and gentle nearshore slope along the Lorain-Erie County line to Cranberry Creek reach and the beaches along the Cranberry Creek to Sawmill Creek reach. The high rates along the Penn Central Railroad bridge to Raccoon Creek reach as well as the low rates along the Kelleys Island reach are largely due to the shore deposits--easily weathered and eroded glaciolacustrine clay for the Sandusky Bay shore and resistant rock for Kelleys Island.

Recession Rates 1937-1973

The modal recession rate was very slow, less than 1 ft/yr (.3 m) and the range in recession rates was very slow to 9-11 ft/yr (2.7-3.3 m) along the mainland shore; the modal recession rate was very slow and the range in recession rates was very slow to between moderate, 3-5 ft/yr (.9-1.5 m) and 15-17 ft/yr (4.5-5.1 m) along the two Sandusky Bay reaches; and the modal recession rate was very slow and the range in recession rates very slow to moderate along the Kelleys Island reach. Overall, the principal factors contributing to low recession rates along the mainland shore include manmade structures, a gentle near-shore slope, and beaches. Manmade structures are the principal factor contributing to low rates along the two Sandusky Bay reaches, particularly the Cedar Point causeway to Penn Central Railroad bridge reach; and the rocky shore is the principal factor contributing to the low rates along the Kelleys Island reach.

Recession Rates 1877-1937 to 1937-1973

For the four reaches for which there are recession rate data for the two periods (Lorain-Erie County line to Cranberry Creek, Cranberry Creek to Sawmill Creek, Penn Central Railroad bridge to Raccoon Creek, and Kelleys Island) the overriding factor contributing to the decrease in the modal recession rate for the mainland and the Sandusky Bay reach and the overall decrease in the range in recession rates is the presence of manmade structures. The increased number of structures, as well as the greater length of shore protected by these structures are responsible for the decrease in the modal recession rates as well as the general decrease in the range in recession rates.

Present and Future Considerations

Corrective measures are being considered for a major problem area, the stretch downdrift of the Huron Harbor jetties. The Buffalo District office of the U.S. Army Corps of Engineers has undertaken a study of the Huron Harbor area at the request of the Ohio Department of Natural Resources. The Corps is authorized under section III of Public Law 483, U.S. 90th Congress, to investigate, study, and construct projects for the prevention or mitigation of shore damages attributable to Federal navigation works. The cost of installing, operating, and maintaining such projects shall be borne entirely by the United States. No such project shall be constructed without specific authorization by Congress if the estimated first costs exceeds $1,000,000...(U.S. Dept. of the Army, 1970, Appendix 1, p. 1-9). It is hoped that within the next few years a solution can be worked out to reduce the effect of the Huron River jetty complex on the downdrift shore.

In addition, another section III study has been undertaken by the Buffalo District office on a smaller, yet more controversial, structure: the jetty-breakwater complex at Vermilion.

If one assumes that the shore of Erie and Sandusky Counties will one day be reasonably well protected from storm waves, there will then be another problem--that of beach sand. Because the shore can be shown to account for much of the sand in the longshore drift system (for example, Carter, 1975, p.2), if the natural supply is not maintained by recession and the sand in the longshore drift system continues to be transported along the mainland shore to the west to be trapped by the jetties at Huron or Cedar Point, then the beaches will decrease in size, the nearshore slope will increase, and the shore will be subjected to greater wave energy. Therefore, if by protecting the shore we lose the source of the sand, but we want beaches and gentle nearshore slopes for shore protection as well as for recreational pursuits, we are going to have to either recycle the sand that we are now trapping, perhaps within cells defined on the downdrift side by major stickout structures, or nourish our beaches with sand from an outside source, presumably offshore deposits.

LORAIN COUNTY

Setting

The moderately to densely built-up Lorain County shore fronts 21 miles (33.7 km) of Lake Erie in north-central Ohio between Erie County to the west and Cuyahoga County to the east. Twenty to twenty-five foot (6-7.6 m) high bluffs and slopes make up the shore, with shale exposed in the wave erosion zone to the west in the Vermilion-on-the-Lake area and to the east, east of the Sheffield Lake area. Till, capped in places by glaciolacustrine clay, makes up the shore in the intervening area. Discontinuous sand beaches, commonly less than 50 feet (15.2 m) wide, front the shore; there is also a variety of shore-protection structures, largely groins and seawalls. There are over 765 structures along the shore; most of these structures are located along the more easily eroded till bluffs and slopes of the central portion of the shore. The most dominant structures are the jetties and breakwaters which surround Lorain Harbor. The nearshore slopes are least offshore of the shale. The water depth 500 feet (152 m) offshore at a lake level elevation of 570.0 feet is about 5 feet (1.5 m) for the areas bordering shale and about 10 feet (3 m) for the areas bordering till. Similarly, for the eastern and western areas bordered by shale, the bottom to 2,000 feet (610 m) offshore consists largely of shale; for the central portion of the shore-bordered by more easily eroded till and glaciolacustrine clay, the bottom is largely till.

Shore Processes

Storm waves appear to be the principal cause of erosion along the shore of Lorain County. Wave erosion removes in-place and slumped material near lake level, thus maintaining an unstable bluff or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits; consequently, the greater the recession rates.

Mass wasting follows wave erosion. Falls, slumps, and flows are most common where there are stratigraphic or structural differences such as bedding planes, zones of laminated clay within the till, or joints. Because of the largely cohesive nature of the shore deposits, failure of a bluff, slope or bank may take place days, weeks, or even months after wave erosion.

Shoreline Changes

The principal change in the Lorain County shore from 1876 to 1973 has been the increase in unevenness of the shore. For the most part the increase is slight along the irregular shale shore fronting the western and eastern portions of the shore and greatest along the intensely developed, more easily eroded central portion of the shore. The change in shape for the most part can be related directly to manmade structures. These structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1876 waves impinged upon a largely natural Lorain County shore. Wave erosion and subsequent mass wasting of the unprotected shore, particularly between Vermilion-on-the-Lake and Avon Lake, provided sand and gravel to form a nearly continuous ribbon of coarse-grained sediment along the shore in the beach and shoreline and nearshore zones. Wave erosion and mass wasting are continuing today, but, because of the manmade structures that have been built along the shore, the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the longshore drift of sand, have had the greatest influence on shoreline changes and recession rates. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate. On the downdrift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate.

Parallel structures--seawalls and breakwaters--have reduced erosion by protecting the base of the shore. Unlike the stickout structures, the parallel structures, which consist largely of seawalls, do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. However, because the principal source of the beach material is the shore, then by protecting the shore the source of beach sediment is largely cut off. Lastly, in general, along stretches in the late period where there is a concentration of structures the recession rate is slower than that of the early period, when there were fewer structures.

Beaches

Along the few stretches where there were wide, greater than 100 feet (30 m) beaches, for example the beach west of the Lorain Harbor structures, the recession rates are very slow or slow. On the other hand, where there were narrow, less than 50 feet (15 m) beaches in combination with a largely unprotected till shore--as along the stretches on either side of the Elyria Waterworks--the recession rates are slow or moderate.

Recession Rates 1876-1937

The modal recession rate was very slow, less than 1 ft/yr (.3 m) and the range in recession rates was very show to moderate 3-5 ft/yr (.9-1.5 m) within this period. In general, the main factors contributing to the low recession rates are rock along the western and eastern portions of the shore and the combination of beaches and manmade structures along the central portion of the shore. For the most part, the stretches which receded at a moderate rate were located in the Lorain area and were fronted by narrow beaches or lacked adequate structural protection.

Recession Rates 1937-1973

The modal recession rate and the range in recession rates were the same as in the 1876-1937 period, very slow, less than 1 ft/yr (.3 m) and very slow to moderate, 3-5 ft/yr (.9-1.5 m). The same factors--rock shore, manmade structures, and/or beaches--contributed to the low recession rates in this period.

Recession Rates 1876-1937 to 1937-1973

Even though the mode and range in recession rates were the same in both periods there was about a 97 percent reduction in the length of shore receding at the moderate rate and a 56 percent reduction in the length of shore receding at the slow rate in the 1937-1973 period. The increased number of structures as well as the greater length of shore protected by these structures is probably the reason for the overall decrease within the recession rate classes. On the other hand, the stretches showing an increase in recession rates (very slow to slow) are for the most part unprotected and downdrift of stickout structures.

Corrective measures are being undertaken to protect Lakeview Park from shore erosion. The 2.5 million dollar project to be financed by the Ohio Department of Natural Resources, the U.S. Army Corps of Engineers, and the City of Lorain began in 1977. The project will protect the shore as well as provide a large sand beach.

CUYAHOGA COUNTY

Setting

The densely built-up Cuyahoga County shore lies along Lake Erie in northeastern Ohio between Lorain County to the west and Lake County to the east. Fifty to sixty foot high (15-18 m) bluffs and slopes made up largely of shale characterize the western shore; manmade structures consisting largely of seawalls and breakwaters characterize the central portion of the shore--which fronts downtown Cleveland, and 25 foot (7.6 m) bluffs and slopes made up largely of till characterize the eastern shore. Discontinuous sand beaches, commonly 50 to 100 feet (15-30 m) wide, front the shore, along with a variety of shore-protection structures. There are many structures along the shore; most of these structures are located along the more easily eroded till of the eastern shore. The most dominant structure is the Cleveland breakwater, which protects about 5 miles of the Cleveland shore from surface waves. The nearshore slopes are comparable along the western and eastern shores. From the western edge of the county to Edgewater Park the bottom to 2,000 feet (610 m) offshore is made up of shale or sand; behind the breakwater the bottom is mud; east of the breakwater to the county line the bottom is largely sand, with shale exposed in the Euclid area. For the most part the sand is thin and rarely has a thickness of more than a few feet.

Shore Processes

Storm waves appear to be the principal cause of erosion along the shore of Cuyahoga County. Wave erosion removes inplace and slumped material near lake level, thus maintaining an unstable bluff or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits; consequently, the greater the recession rates.

Mass wasting follows wave erosion. Falls, slumps, and flows are most common where there are stratigraphic or structural differences such as bedding planes, zones of laminated clay within the till, or joints. Because of the largely cohesive nature of the shore deposits, failure of a bluff, slope, or bank may take place days, weeks, or even months after wave erosion.

Shoreline Changes

The principal change in the Cuyahoga County shore from 1876 to 1973 has been the increase in unevenness of the shore. For the most part, the increase is slight along the western and eastern reaches and marked behind the Cleveland breakwater, where there has been extensive manmade modification (fill). The change in shape for the most part can be related directly to manmade structures. These structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1876, waves impinged upon a largely natural Cuyahoga County shore. Wave erosion and subsequent mass wasting of the unprotected shore, particularly east of the Cuyahoga River, provided sand and gravel to form a nearly continuous ribbon of coarse-grained sediment along the shore in the beach and shoreline and nearshore zones. Wave erosion and mass wasting are continuing today, but, because of the manmade structures that have been built along the shore, the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the longshore drift of sand, have had the greatest influence on shoreline changes and recession rates. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate; on the downdrift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate.

Parallel structures--seawalls and breakwaters--have reduced erosion by protecting the base of the shore. Unlike the stickout structures, the parallel structures, which consist largely of seawalls, do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. However, because the principal source of the beach material is the shore, by protecting the shore the source of beach sediment is largely cut off. In general, in the late period along stretches where there is a concentration of structures, the recession rate is slower than that in the early period, when there were fewer structures.

Beaches

Along the few stretches where there were wide, greater than 100 feet (30 m) beaches, for example the beach on the updrift (west side) of the jetty at Euclid Creek--the recession rate within a given period was very slow. On the other hand, where there were narrow, less than 50 feet (15 m), beaches in combination with a largely unprotected shore--as along the stretch downdrift of the jetty at Euclid Creek--the recession rate was slow.

Recession Rates 1876-1937

The modal recession rate was very slow, less than 1 ft/yr (.3 m) and the range in recession rates was very slow to slow, 1-3 ft/yr (.3-.9 m) within this period. In general, the main factors contributing to the low recession rates are the rock shore along western Cuyahoga County and combinations of beaches, manmade structures, or rock shore along eastern Cuyahoga County.

Recession Rates 1937-1973

The modal recession rate and the range in recession rates were the same as in the 1876-1937 period, very slow, less than 1 ft/yr (.3 m), and very slow to slow, 1-3 ft/yr (.3-.9 m). The same factors--rock shore, manmade structures, and/or beaches--contributed to the low recession rates in this period.

Recession Rates 1876-1937 to 1937-1973

Even though the mode and range in recession rates were the same in both periods there was about an 80 percent reduction in the length of shore receding at the slow rate in the 1937-1973 period. The increased number of structures as well as the greater length of shore protected by these structures is probably the reason for the overall decrease within the recession rate class of slow. On the other hand, the stretches showing an increase in recession rates (very slow to slow) are for the most part unprotected and downdrift of stickout structures.

LAKE COUNTY

Setting

Lake County, one of eight Ohio counties that border the southern shore of Lake Erie, lies along the eastern part of the Ohio shore and is bordered on the lake by Ashtabula County to the east and Cuyahoga County to the west. The shoreline length of Lake County is about 30 miles (48 km).

The shore can be divided into two geographic areas, which are separated by the Grand River. The shore west of the river is for the most part urban and built up, whereas the shore east of the river is more sparsely settled and there is some agricultural and forest land. The more densely populated centers include Willowick, Eastlake, Mentor-on-the-Lake, Mentor Headlands, Fairport Harbor, and Madison-on-the-Lake.

The shore is made up of 30 to 40 foot (9-12 m) high bluffs and slopes composed of till overlain by glaciolacustrine deposits. Lakeward of the shore are narrow sand beaches (generally several tens of feet wide) and gentle nearshore slopes [about one degree within 500 feet (152 m) of the shoreline]. Along this shore erosion is the crucial process. Erosion of in-place or slumped material by storm-generated surface waves reduces the resisting moment at the base of the bluff or slope, leading to and perpetuating shore recession.

The Lake County shore has a flat, glaciated appearance that is interrupted here and there by small hills or stream valleys. From the Cuyahoga-Lake County line to Redbird this appearance changes abruptly at the shoreline, where 30 to 40 foot (9-12 m) bluffs and/or irregular hammocky slopes commonly mark the interface between the land and the lake. At Redbird and east to the Lake-Ashtabula County line and landscape is much less precipitous, and banks and gentle slopes less than 15 feet (5 m) high are common.

Aside from the shore-lake interface, the most noticeable topographic breaks are the river valleys. Both the Chagrin and Grand Rivers have cut wide, deep channels into the surficial depostis; the Mentor Harbor-Mentor Marsh depression is an abandoned Grand River channel. East of Fairport Harbor, the valley of Chapel Creek in Madison Township is the most noticeable topographic break.

There are four principal deposits that make up the Lake County shore: shale (the bedrock), till, glaciolacustrine clay, the glaciolacustrine sand. These deposits are best exposed along the lakeshore bluffs, although exposures can be found in and along the stream channels.

Shale underlies the entire Lake County study area. The shale contains thin resistant siltstone beds and has a northeast strike and a gentle southeast dip.

Along the entire county shoreline the bottom surface to about 2,000 feet (610 m) offshore has a slope of less than one degree. However, the slope is not constant; in general the slope decreases from the western border to the eastern border of the county. For example, the mean water depth 2,000 feet (610 m) from the shoreline west of Grand River was 24 feet (7 m), with a range of 14.5 to 30 feet (4-9 m), whereas the mean water depth 2,000 feet (610 m) from the shoreline east of Grand River was 21 feet (6 m), with a range of 17 to 24 feet (5-7 m). Within 500 feet (152 m) of the shoreline--in the zone where most of the wave energy is expended on the bottom--the mean water depth is less than 13 feet (4 m). At 500 feet (152 m) the depth of the water decreases from about 13 feet (4 m) along the westernmost reach to about 9 feet (3 m) along the easternmost reach. Structures have influenced the slope in places. The natural slope west of Grand River has been reduced because of sand accumulation on the windward side of the west jetty at Grand River. Just to the east of the Grand River a scarcity of sand has contributed to a steeper slope.

Sand beaches, which differ greatly in size, form a discontinuous ribbon along nearly the entire Lake County shoreline. The longest continuous stretch of moderate-to-large (greater than 50 feet (15 m) wide) beaches is from North Perry Park to the Lake-Ashtabula County line. Other sizeable beaches are present on the windward (west) side of the jetties at Chagrin River, Mentor Harbor, and Grand River.

The beaches are composed of medium-to very coarse grained, subangular to subrounded, well-sorted sand composed largely of rock fragments and quartz. The beaches from the Cuyahoga-Lake County line to Grand River have an average thickness of about 5 feet (1.5 m), whereas the beaches east of Grand River to the Lake-Ashtabula County line have an average thickness of about 3 feet (1 m). Most of the beaches west of Grand River lie on till; the beaches east of Grand River lie on shale.

Manmade structures as well as sand beaches are a significant part of the Lake County shoreline. Almost without exception such structures have a direct effect on the physical processes operating along the shoreline. The structures can be divided into four basic types: breakwaters, jetties, groins, and seawalls. Included in the 402 structures are 26 breakwaters, 13 jetties, 200 groins, 46 groin fields, and 81 seawalls. The structures range in size from a few feet wide and several feet long to several feet wide and several hundred feet long. Groins and seawalls are distributed along the entire shoreline, whereas breakwaters and jetties are located primarily at the mouths of rivers and harbors. The number of structures is directly proportional to land development. The 195 structures located west of Grand River are fairly evenly distributed along the built-up shoreline. Along the sparsely populated shore between Grand River and the Redbird area and the Lake-Ashtabula County line, a much more built-up shoreline only about half the length of the Grand River to Redbird shoreline, there are 128 structures.

Shore Processes

Shore erosion can be related to many processes, but along the Lake County shore, there are two principal shore erosion processes: wave erosion and mass wasting. Of the two processes, wave erosion is by far the more significant. These processes erode the shore at different rates because of two primary factors: the physical setting and the weather. Variation in recession rates among different reaches along the shore and through time generally can be related to these two factors. Along the shore of Lake County the principal mass-wasting processes are block falls, rotational slumps, debris flows, and piping.

Block falls are common along the high till bluffs east of Painesville-on-the-Lake; rotational slumps are common along most of the Lake County shore, especially between Mentor Harbor and Camp Roosevelt. Debris flows are common in the thick clays east of Camp Roosevelt; and piping is common in the thick sands of Camp Roosevelt.

Shoreline Changes

The best approximation for a natural (pre-structure) recession rate is the rate during the 1876-1937 period; the modal recession rate in this period was slow. In the 1937-1973 period the modal rate was very slow, although there was a sizeable length (15 percent) of the reach that receded at a moderate rate. The greater variability in the recession rates in the 1937-1973 period than in the 1876-1937 period resulted from the manmade structures. Seawalls and similar structures help protect the shore immediately landward of the structures. Groins and similar stickout structures, by trapping sand on the updrift side, reduce the nearshore slope and widen the beach to help protect the updrift shore. At the same time, however, these types of structures deprive the downdrift shore of sand, increase the nearshore slope, narrow the beach, and thus contribute to accelerated recession rates downdrift. This is particulary true along structurally unprotected areas immediately downdrift of substantial structures. Further evidence of this influence can be seen in the more irregular shoreline shape in the 1937-1973 period especially in areas protected by stickout structures adjacent to unprotected areas. Overall, the recession rates have been reduced by these structures from slow to very slow in some areas and have been increased from slow to moderate in other areas.

Study of maps and aerial photographs of Lake County shows major shoreline changes between 1976 and 1973. In 1876 the Lake County shoreline had a fairly even outline and was fronted by a continuous beach and several manmade structures. In 1973 the shore had an uneven outline and was fronted by discontinuous beaches and about 400 manmade structures. These changes in outline, beaches, and manmade structures are reflected in recession rates, determined from a 1:4,800 recession-line map of the entire county shore. The principal rate of recession decreased from slow, 1-3 ft/yr (.3-.9 m), in the 1876-1937 period to very slow, less than 1 ft/yr (.3 m), in the 1937-1973 period. However, the range of recession rates increased from very slow to moderate 3-5 ft/yr (.9-1.5 m) to very slow to very rapid 7-9 ft/yr (2.2.7 m).

Manmade structures are the principal cause of these changes in recession rates. The increased number of structures has helped protect the shore from wave erosion by trapping sand (groins) or by directly armoring the shore (seawalls). On the other hand, the few large jetties and large groins, by significantly disrupting the longshore drift, have caused a downdrift increase in nearshore slope and a decrease in beach width, leading to accelerated wave erosion of the shore downdrift of these structures.

The longshore drift is primarily from southwest to northeast. Reversals in longshore drift to take place from time to time, especially during the northeast storms, but, because of the shoreline orientation and the greater fetch for onshore winds from the west, the overall result is a net drift to the northeast. Evidence for this west-to-east movement is seen most readily on the windward (west) side of large structures such as the intake jetties at Chagrin River, the Mentor Harbor jetties, and the Grand River jetties, where large amounts of sand have been trapped by the structures.

Because of the somewhat northerly orientation of the shore from the Cuyahoga-Lake County line to Grand River, the longshore drift along this part of the shore is probably more unidirectional than it is from Grand River to the Lake-Ashtabula County line, where the shore has a more easterly orientation and is less sheltered from easterly winds.

Recession Rates 1876-1937

The recession rates were quite consistent in this period. A slow, 1-3 ft/yr (.13-.9 m), rate was exceeded only in a 650-ft (198 m) stretch that had a moderate (3-5 ft/yr) recession rate. This stretch receding at a moderate rate was unprotected by structures in 1937; however, there were stickout structures on either side of the stretch.

Recession Rates 1937-1973

The recession rates in this period were mainly very slow, less than 1 ft/yr (.3 m) and slow, although two stretches with a combined length of over one-half mile (over 800 m), receded at a moderate rate. Both of these stretches were structurally unprotected and lay adjacent to and east of substantial stick-out structures. In general, areas that have a high structure density have lower recession rates than areas with a low structure density.

ASHTABULA COUNTY

Setting

The sparsely to moderately built-up Ashtabula County shore lies along Lake Erie in northeastern Ohio between Lake County to the west and Pennsylvania to the east. The shore deposits, which are composed largely of till, make up the banks, bluffs, and slopes, which increase in elevation from about 15 feet (5 m) along the western edge of the county to about 65 feet (20 m) along the eastern half of the county. Discontinuous sand beaches, commonly 50 to 100 feet (15 to 30 m) wide, front the shore. There are a variety of shore-protection structures along the shore as well as two major jetty complexes which extend out into the lake for several hundred feet (a few hundred meters). The nearshore slope is gentle and fairly constant along the entire county. The average water depth 500 feet (152 m) offshore at a lake-level elevation of 570.0 feet is about 6 feet (2 m). The nearshore bottom within 2,000 feet (610 m) of shore consists of a narrow (a few to several hundred feet wide) band of sand adjacent to the shore and shale farther offshore. The sand for the most part is no more than 3 feet (1 m) thick.

Shore Processes

Storm waves appear to be the principal cause of erosion along the shore of Ashtabula County. Wave erosion removes in-place and slumped material near lake level, thus maintaining an unstable bluff or slope. Lake level is a major factor in this process. The higher the lake, the closer the waves break to the shore and the greater the wave energy expended on the shore deposits. Consequently, high lake levels cause greater recession rates.

Mass wasting follows wave erosion. Falls, slumps, and flows are most common where there are stratigraphic or structural differences such as bedding planes, zones of laminated clay within the till, or joints. Because of the largely cohesive nature of the shore deposits, failure of a bluff, slope, or bank may take place days, weeks, or even months after wave erosion.

Shoreline Changes

The principal change in the Ashtabula County shore from 1876 to 1973 has been the increase in unevenness of the shore. The 1876 shore, with the exception of the Ashtabula and Conneaut areas, had a fairly even, uniform shape, whereas the 1973 shore has a much more uneven, nonuniform shape. The change in shape can be related directly to manmade structures.

These structures are also largely responsible for the changes in beach size and distribution.

Structures

In 1876 waves impinged upon a largely natural Ashtabula County shore. Wave erosion and subsequent mass wasting of the unprotected shore provided sand and gravel to form a nearly continuous ribbon of coarse-grained sediment along the shore in the beach, shoreline and nearshore zones. Wave erosion and mass wasting are continuing today, but, because of the manmade structures that have been built along the shore, the effect of the waves has been altered. The structures, largely by disrupting the longshore drift of sand and/or by armoring the shore, have caused a decrease in the recession rates along some stretches and at the same time have caused an increase in the recession rates along other stretches.

Stickout structures--largely groins and jetties--by modifying the longshore drift of sand, have had the greatest influence on shoreline changes and recession rates. Entrapment of sand on the updrift side of a structure results in a wider beach and a gentler nearshore slope. The increase in beach width and decrease in the nearshore slope on the updrift side reduce the amount of wave energy impinging upon the shore and cause a decrease in the recession rate; on the downdrift side the decrease in beach width and increase in nearshore slope increase the amount of wave energy impinging upon the shore, causing an increase in the recession rate.

Parallel structures--seawalls and breakwaters--have reduced erosion by protecting the base of the shore. Unlike the stickout structures, the parallel structures, which consist largely of seawalls, do not appear to have a detrimental effect on the adjacent shore because these structures do not directly affect the longshore transport of sand. However, because the principal source of the beach material is the shore, by protecting the shore the source of beach sediment is largely cut off. In general, in more recent time, along stretches where there is a concentration of structures, the recession rate is slower than that in the earlier period, when there are fewer structures.

Beaches

In stretches where there were wide beaches, greater than 100 feet (30 m), for example the beaches on the updrift (west side) of the jetties at the Ashtabula River and at Conneaut Creek, the recession rate within a given period was very slow. On the other hand, where there were narrow beaches, less than 50 feet (15 m), in combination with an unprotected shore--as along stretches downdrift of stickout structures between

Geneva-on-the-Lake and Ashtabula--the recession rates were slow to moderate.

Recession Rates 1876-1938

The modal recession rate was very slow, less than 1 ft/yr (.3 m), and the range in recession rates was very slow to moderate, 3-5 ft/yr (.9-1.5 m) within this period. In general, the main factors contributing to the low recession rates are the gentle nearshore slopes and the beaches. The gentle nearshore slopes have helped to protect the shore along the entire county, as have the beaches except for the reach directly downdrift of the Ashtabula jetties. This reach, the Ashtabula River to Whitman Creek reach, is the only one to have moderate recession rates. The structures, in trapping sand from the west-to-east longshore drift, have deprived the downdrift reach of sand, thereby reducing the beach width and contributing to the relatively high recession rates.

Recession Rates 1938-1973

The modal recession rate was very slow, less than 1 ft/yr (.3 m), and the range in recession rates was very slow to rapid, 5-7 ft/yr (1.5-2.1 m) within this period. As in the 1876-1938 period, the main factors contributing to the overall low recession rates are the gentle nearshore slopes and the beaches. The stretches receding at moderate and rapid rates are located downdrift of structures which lie between the Lake-Ashtabula County line and Red Brook.

Recession Rates 1876-1938 to 1938-1973

The overall, but slight, reduction within the recession rate classes from the 1876-1938 period to the 1938-1973 period can most likely be related to the manmade structures. The increased number of structures, as well as the greater length of shore protected by these structures, is probably the reason for the decrease within the recession rate classes, whereas the stretches showing an increase in recession rates are unprotected and for the most part downdrift of stickout structures.

POTENTIAL PROTECTION CONSIDERATIONS

The recession rates along the entire shore of Lake Erie vary from one location to another. Areas with shore lengths up to a few hundred feet, (less than 100 m) can probably be most easily protected by manmade structures, particularly if the stretch is between protected areas. The type of protection naturally will depend on the physical setting. Stretches with shore lengths up to several hundred feet (greater than 100 m) can be protected by either a nonstructural method such as increasing the supply of sand along the stretch (beach nourishment) or a combination nonstructural and structural method such as increasing the supply of sand as well as building structures to retain it.

The shore accounts for much of the sand in the longshore drift system. If the natural supply is not maintained by recession and the sand in the longshore drift system continues to be transported along the mainland shore then the beaches will be subjected to greater wave energy. Therefore, by protecting the shore we lose the source of the sand, but because we want beaches and gentle nearshore slopes for shore protection as well as for recreational pursuits, we are going to have to either recycle the sand that we are now trapping, perhaps within cells defined on the downdrift side by major stickout structures, or nourish our beaches with sand from an outside source, presumably offshore deposits.

Last but not least, in any consideration of solutions for shore protection is lake-level regulation. A decrease in the level of the lake would reduce the amount of wave energy reaching the shore; the greater the decrease in lake level, the greater the decrease in wave energy reaching the shore. Perhaps in the distant future, if shoreland becomes expensive enough and lake sedimentation becomes a tangible problem, this solution will become feasible enough to help protect the entire Lake Erie shore.

II
FLOODING

Introduction

No geographic area in Ohio is more inherently ripe for conflict than where the land and water meet. This is expecially true in regard to the threat of flooding. The flooding problem along the Lake Erie shoreline is especially hazardous since it is plagued by floods resulting from riverine and lake sources including the critical area where these two forces collide. The damage suffered in the coastal area in the past and the continual threat of flooding in the future make this an issue of vital concern in Ohio's Coastal Zone Management Program.

Geological History

Four major phases of glaciation have formed the relief and drainage pattern of the Great Lakes Basin. The sediments that overlay the bedrock consist of glacial drift deposited by the continental ice sheets, streams created by the melting ice, stratified beds laid down in ancient glacial lakes, and sand consisting of materials picked up and redeposited by the wind. These unconsolidated, readily erodible sediments have been partially reworked by post-glacial streams and deposited as alluvium in the Great Lakes and their flood plains.

There is also a slow geological tilting of the earth's surface around Lake Erie. The southwest part of the basin is being lowered at the rate of about one foot per century. It is believed that this is a consequence of the "springing back" of the earth's surface at the northeast end of the basin after the last glacier retreated.

Natural Attraction

Geographic location is the key in the history of Ohio's shoreline development. From the first fur traders and settlers to the current thousands of businesses and residents in the coastal area it was the attractiveness of the lake and its estuaries that has influenced development patterns and location. The advantage of large quantities of water for transportation, power, industry, human consumption, and recreation was evident from the beginning.

Although the advantages of such locations for many of these needs has faded with modern technology, the desire to locate along the lake still influences development patterns in the coastal area. Today, the aesthetic aspect is one of the most influential attraction factors in lake-shore location.

Unfortunately the lack of understanding or adequate consideration of the natural forces associated with shoreline locations has created a critical flood hazard for a considerable portion of the region's coastal development. This lack of consideration must be corrected in future development plans so that succeeding generations are not plagued by the problem and financial burden of flood-prone development. The consideration of flood-prone areas and the adoption of regulatory controls on development in these areas is referred to as flood plain management. A review of the natural flooding processes will give us a better appreciation of the need for flood plain management.

Riverine Flooding

Flooding may occur at any time, but throughout the Lake Erie region most major floods have occurred during late winter or early spring. Rainfalls combined with snowmelt on frozen or nearly saturated ground during these seasons produce peak runoff conditions and have created very destructive floods. The problem is often aggravated by ice jams in the bends of stream channels and at the mouths of the streams emptying into the lake. The problem is complicated further when the lake is frozen. Flood waters can not get out into the lake during these conditions and they are "backed up" in the stream channel increasing flood heights upstream. Severe thunderstorms during the summer months have also produced destructive floods, although damage is usually confined to local tributary areas.

Rapid urbanization has contributed another aspect to the flooding problem. Intensified storm runoff in metropolitan areas overloads existing drainage systems which have not kept pace with the rate of growth. This creates higher flood levels in existing flood-prone areas, sewer backup conditions, and new flood-prone areas due to the increased flood levels. Many of these flood problems have been aggravated by the loss of flood storage and carrying capacity in the flood plains due to continued development and filling in these areas. This causes even higher flood levels.

The flood plain of a river or stream is the area of a river channel and the adjacent land, built up by sediments of the present stream regime, which is covered with water during maximum flood stages. Since the maximum flood stage can never be technically known, common practice is to refer to a flood plain of a particular frequency of occurrence or magnitude. For example the 100 year flood plain (the standard for state and federal government programs) is the area flooded by the stage associated with a hundred year frequency flood. A hundred year frequency flood is a flood which has a one percent chance of being exceeded in any year. Although calculation of possible recurrence is often based upon historical records, there is no guarantee that a 100 year flood will occur with a 100 year period or that it will not recur several times during that period.

A riverine flood plain (Figure 1) can be divided into two zones or areas for regulatory purposes--the floodway and the flood fringe (also called floodway fringe). The floodway is the portion consisting of the stream channel and overbank areas necessary to convey the flood discharge without increasing flood heights and velocities above adopted levels. The floodway is usually not limited to the actual stream channel. Rather it is the area calculated to be of sufficient width and flood conveyance characteristics to pass the flood waters along a reach of stream without increasing flood heights more than the stated level (one foot, one-half foot, etc.) or substantially increasing velocities over what they would have been without the assumed confinement. In this calculation the floodway itself is assumed to remain in an open condition (or condition at time of calculation). Floodway areas are subject to frequent, high velocity flooding, often at considerable depths.

The flood fringe area is the portion of the regulatory flood plain beyond the limits of the floodway. It is subject to less frequent, lower velocity flooding and does not play a major role in passing flood flows; however, it does provide storage area during the flooding event.

With flood plain regulation, development is tightly controlled in the floodway to preserve flood flow capacities and protect public safety. In the flood fringe areas most land uses are permitted, provided they are individually protected to a level above the regulatory flood. Unless local flood plain regulation programs are adopted and enforced, flooding problems will continue to compound an already hazardous condition and create a financially unacceptable public burden.

Lake Flooding

Flooding along Lake Erie occurs when conditions in or on the lake cause water levels to rise above normal. The level of Lake Erie is the result of an integration of the hydraulic characteristics of the connecting channels of the other Great Lakes and the St. Lawrence River and the total water supplies received (Figure 2). The total water supplies are the inflows from Lake Huron, plus the runoff from the land in the Lake Erie Basin, plus the precipitation falling directly on the lake, less the evaporation from the lake. Figure 3 shows the numbers for these water supply factors for an average ten-year period which includes both high and normal supplies.

The level of Lake Erie depends on the balance between the total water supplies received and its discharge to Lake Ontario. If supplies received are greater than those discharged the lake level gradually rises. Conversely, if the discharge is greater than supplies received the lake level slowly drops. These hydrologic factors are the dominant cause of the protracted fluctuations in the levels of Lake Erie.

Precipitation in the form of rain and snow is the source of all water supplies to the Great Lakes. The low lake levels during the mid-1930's and 1960's were the result of abnormally low precipitation, while the high lake levels of the early 1950's and 1970's were caused by excessive precipitation. The annual precipitation in the Lake Erie Basin has varied from 24.5 to 42.6 inches. The peak runoff usually occurs in March; however, high runoffs also occur during the fall and winter as a result of rainfall and snowmelt when land evaporation and transpiration is least and the ground is either saturated or frozen. Such was the case in 1972 with the high water levels.

The higher levels in the spring and early summer and gradual lowering of levels the remainder of the year reflect the variations of runoff and evaporation in the Lake Erie Basin. In any given year the variations from winter lows to summer highs are small, usually averaging about one and one-half foot.

These natural phenomena are the dominant causes of the long-term fluctuations of the Great Lakes. The mean monthly levels for Lake Erie since 1860 are shown in Figure 4. The magnitude and duration of these fluctuations are irregular and for this reason high and low water levels do not occur in any regular cycles.

The most dramatic changes in water levels are the short-term fluctuations caused by strong winds and by sharp differentials in barometric pressure. They usually are of short duration, lasting less than one day, and do not represent any changes in the volume of water in the lake.

The winds are caused by the passage of weather systems. The strong winds which cause most of the shoreline damage occur primarily in the spring and fall. Winds keep the water surface of the lake in constant motion and influence the littoral currents which build and destroy the beaches.

During periods of strong winds, deep water waves generated by the wind can reach a height in excess of 25 feet from trough to crest. It is the energy released by these waves as they break on the shore that causes erosion. When superimposed on high water levels, the damage caused by waves is increased. This is illustrated in Figure 5. Strong winds tend to build up the level at the downwind shore and reduce the water level along the upwind shore. Sustained high winds along the southwesterly axis of Lake Erie have caused differences in the water levels between Buffalo and Toledo of up to 13 feet. Movement of weather systems can produce local changes in atmospheric pressures which in turn cause sudden changes in water levels.

In summary, the principal cause of long-term water level fluctuations on Lake Erie is extended periods of excessive or deficient precipitation. The regular annual fluctuations in levels are due to seasonal variation in water supplies. The short-term fluctuations are the result of wind and meteorological disturbances. When the high seasonal or annual variations accompany high long-term fluctuations the effects are exaggerated and flooding can be quite severe.

Since coastal flood conditions differ from riverine flooding, the lake flood plain also differs. Lake flood plains do not have floodway areas since they do not convey flood discharges. However, most of the inundated area of the lake flood plains is susceptible to damaging wave action at the same time. Therefore, the hazard to development is uniform throughout the lake flood plain area. For this reason development should be discouraged in the lake flood plain area unless it can be constructed above the lake flood levels or otherwise protected to that level. The 100 year flood level is the recommended standard for regulatory programs in lake flood plains as well as riverine flood plains.

Flood Plain Information

An effective flood plain regulation program, whether it includes riverine flood plains, lake flood plains, or both, requires a firm commitment on the part of local and state governments to enforce the standards and safeguards necessary in dealing with the flood hazard. This requires adequate flood plain data to support the regulations and their implementation. Since the beginning of Ohio's CZM program, the State has given priority to the Lake Erie shoreline area in its flood plain delineation program. The primary source for detailed flood plain information is through the National Flood Insurance Program. The U.S. Army Corps of Engineers's efforts in flood plain information have been reoriented to the completion of flood insurance studies. The flood insurance studies provide the detailed flood information necessary for supporting local flood plain regulation programs. Table 1 provides a current list and status of flood insurance studies for the coastal counties. Other, less detailed flood information is also available from U.S. Army Corps of Engineers, U.S. Geological Survey and Soil Conservation Service studies.

Management Considerations

The main emphasis of Coastal Zone Management is to promote the wise use of the coastal resources. The following management considerations are set forth in accordance with that premise.

1. A local flood plain regulation program should be adopted and enforced in all coastal communities (municipalities and unincorporated county areas). Criteria should be adopted to prohibit structural development in the floodway portion of the 100 year frequency flood plains. Construction in flood fringe and lake flood plains should be allowed only if protected to levels above the 100 year flood elevations, either by fill or other standard flood proofing measures.

2. All coastal communities should participate and maintain eligibility in the National Flood Insurance Program. Flood insurance coverage is available to protect existing buildings against flood and flood-related damages including flood related erosion damages.

3. New construction in urban and other developing areas should be designed such that the resultant runoff from these areas would not appreciably increase above levels prior to development.

4. Statewide support should be continued for the International Joint Commission's proposal for lowering levels of Lake Erie by a diversion channel in Squaw Island, New York.

5. Deed descriptions for property in flood hazard areas should include a statement concerning the flood-prone nature of that respective property.

DATE DUE

GAYLORD	No. 2333		PRINTED IN U.S.A.

Ohio Department of Natural Resources
Fountain Square · Columbus, Ohio 43
JAMES A. RHODES, *Governor* • ROBERT W. T